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METEOROLOGY.—*Evaporation in the great plains and intermountain districts as influenced by the haze of 1912.* LYMAN J. BRIGGS and J. O. BELZ, Bureau of Plant Industry.

It has recently been shown by Abbot and Fowle[1] and by Kimball,[2] that the haze of 1912, presumably due to the eruption of Mt. Katmai on June 6 and 7, 1912, gave rise to a marked diminution in the intensity of the solar radiation at the earth's surface. Abbot and Fowle found that the total direct radiation of the sun was reduced about 20 per cent at Bassour, Algeria, and also at Mt. Wilson, California, when the effect reached its maximum in August. Kimball reports an average reduction of 17 per cent in the intensity of the solar radiation received at Mt. Weather, Va., during the last half of 1912, while at Madison, Wis., an average reduction of 14 per cent was observed for the same period.

During the past five years the writers have been engaged in a series of evaporation measurements[3] in the great plains and intermountain districts, and it has seemed desirable to determine to what extent the reduction in the solar intensity during 1912 affected the evaporation. In making such a comparison, it must of course be recognized that evaporation is profoundly in-

[1] Smithsonian Miscellaneous Collections, **60**: 29. 1913.

[2] This Journal, **3**: 269. 1913. Also, Bull. Mt. Weather Observatory, **5**: 295. 1913.

[3] In coöperation with the Office of Dry Land Agriculture, and the Office of Western Irrigation Agriculture, of the Bureau of Plant Industry.

fluenced by a number of other factors, such as temperature, cloudiness, humidity, and wind velocity. In any comparison of this kind one would, therefore, expect to encounter anomalies in the records from an individual station resulting from these disturbing factors (see Table III).

The evaporation records are based upon daily measurements of the change in elevation of a free water surface, after correcting for precipitation. The evaporation tanks are either 6 or 8

TABLE I

NORMAL EVAPORATION AT STATIONS IN THE GREAT PLAINS AND INTERMOUNTAIN DISTRICTS

STATIONS	NO. OF YEARS OBS.	APRIL	MAY	JUNE 1–15	JUNE 16–30	JULY	AUGUST	SEPT.	TOTAL Apr. 1 to Oct. 1
		inches	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*
Amarillo, Tex.	5	7.55	9.09	5.22	5.54	9.68	9.06	8.00	54.14
Dalhart, Tex.	4	7.89	9.73	5.70	6.25	10.56	10.04	8.26	58.43
Garden City, Kans.	4	7.61	8.76	4.63	5.51	10.00	9.35	7.69	53.55
Hays, Kans.	5	6.85	7.26	4.24	4.61	9.09	8.82	6.96	47.83
Akron, Col.	4	5.43	6.91	4.10	4.43	9.36	8.61	6.85	45.69
North Platte, Neb.	5	6.05	6.75	3.72	4.79	8.50	7.74	6.44	43.99
Newell, S. Dak.	4	4.81	6.49	3.44	4.53	9.23	7.53	5.54	41.57
Edgeley, N. Dak.	5	3.89	4.87	2.24	3.42	6.91	5.88	4.31	31.52
Dickinson, N. Dak.	5	4.08	5.03	2.55	3.65	7.34	6.31	4.28	33.24
Williston, N. Dak.	3	4.72	6.11	2.79	4.04	7.92	6.24	4.11	35.93
Judith Basin, Mont.	3	4.10	5.40	2.86	3.25	7.61	6.94	4.86	35.02
Nephi, Utah	4	4.80	7.21	4.25	4.82	9.67	9.23	6.13	46.11
San Antonio, Tex.	5	5.93	6.57	4.44	4.83	9.61	9.55	7.24	48.17
Fallon, Nev.	4	6.20	8.34	4.91	4.99	11.05	10.05	6.14	51.68
Yuma, Ariz.	3	8.34	10.92	5.92	5.59	11.33	11.10	8.19	61.39
Σn		88.25	109.44	61.01	70.25	137.86	126.45	95.00	

feet in diameter, and 2 feet deep, and are sunk in level ground in a freely exposed space to within 4 inches of the top, the water level being maintained at approximately 4 inches below the top of the tank.

At most of the evaporation stations, "normals" based upon at least four years records, exclusive of those of 1912, are now available. The monthly normal evaporation, from April to September inclusive, for 15 stations located in the great plains and in-

termountain districts, is given in Table I. Since the eruption of Mt. Katmai occurred early in June, the records for this month are divided into two parts. At the foot of the table is given the sum of the combined evaporation occurring at the 15 stations for each month, designated as Σn. In Table II is given the evaporation for the corresponding periods during the summer of 1912, the combined evaporation for all of the stations during

TABLE II

EVAPORATION IN 1912 AT STATIONS IN THE GREAT PLAINS AND INTERMOUNTAIN DISTRICTS

STATIONS	APRIL	MAY	JUNE 1-15	JUNE 16-30	JULY	AUGUST	SEPT.	TOTAL Apr. 1 to Oct. 1
	inches	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*
Amarillo	7.05	9.90	4.95	4.04	10.95	9.49	6.49	52.87
Dalhart	8.21	10.24	4.64	3.84	11.10	9.13	6.75	53.91
Garden City	6.86	10.82	4.77	3.81	10.64	9.15	7.09	53.14
Hays	6.08	8.28	3.13	3.29	9.99	9.18	7.02	46.97
Akron	4.68	7.10	2.90	3.85	7.62	7.05	4.65	37.85
North Platte	4.84	7.54	2.80	4.80	8.97	7.46	5.29	41.70
Newell	4.85	6.42	3.65	4.53	7.98	6.60	3.71	37.74
Edgeley	3.69	4.60	2.33	2.67	5.69	4.24	2.74	25.96
Dickinson	3.65	4.67	2.26	3.26	6.02	5.92	3.21	28.98
Williston	3.88	4.78	3.81	3.29	5.98	4.99	2.98	29.71
Judith Basin	2.62	4.14	2.74	3.66	5.97	6.24	3.42	28.79
Nephi	3.54	6.30	4.20	5.08	9.24	8.89	6.16	43.41
San Antonio	4.08	7.61	3.56	3.50	10.59	10.65	8.55	48.54
Fallon	5.67	7.46	5.24	5.36	9.64	8.89	6.07	48.33
Yuma	7.29	9.00	5.46	4.78	9.44	9.00	7.62	52.59
Σe	76.99	108.86	56.44	59.76	129.82	116.88	81.75	
$\Sigma e/\Sigma n$	0.87	0.99	0.92	0.86	0.94	0.92	0.86	

each period being given at the foot of the table and designated as Σe.

In comparing the evaporation during 1912 with the normal evaporation, two procedures have been followed. *First*, the ratio ($\Sigma e/\Sigma n$) of the total evaporation occurring at all of the stations during a given month in 1912 to the normal evaporation for that period has been calculated (Table II). *Second*, the ratio of the

evaporation at a given station during a given month in 1912 to its normal evaporation for the corresponding period has been determined, and the mean of these ratios for all stations for each month has been computed, together with the probable error. These results are given in Table III. The results of the two methods of comparison will be seen to be in good agreement. The mean value is given in Table IV, with the corresponding ratios

TABLE III

RATIO OF THE MONTHLY EVAPORATION IN 1912 AT EACH STATION TO THE NORMAL EVAPORATION

STATIONS	APRIL	MAY	JUNE 1-15	JUNE 16-30	JULY	AUGUST	SEPTEMBER
Amarillo, Tex.	0.93	1.09	0.95	0.73	1.13	1.05	0.81
Dalhart, Tex.	1.04	1.05	0.81	0.61	1.05	0.91	0.82
Garden City, Kans.	0.89	1.24	1.03	0.69	1.06	0.99	0.92
Hays, Kans.	0.89	1.14	0.74	0.71	1.10	1.04	1.01
Akron, Colo.	0.86	1.03	0.71	0.87	0.81	0.82	0.68
North Platte, Neb.	0.80	1.12	0.75	1.00	1.06	0.96	0.82
Newell, S. Dak.	1.01	0.99	1.06	1.00	0.86	0.88	0.67
Edgeley, N. Dak.	0.95	0.94	1.04	0.78	0.82	0.72	0.64
Dickinson, N. Dak.	0.89	0.92	0.89	0.89	0.83	0.94	0.75
Williston, N. Dak.	0.82	0.78	1.14	0.81	0.75	0.80	0.77
Judith Basin, Mont.	0.64	0.77	0.96	1.13	0.78	0.89	0.90
Nephi, Utah	0.74	0.87	0.99	1.05	0.96	0.96	1.00
San Antonio, Tex.	0.69	1.16	0.80	0.72	1.10	1.12	1.13
Fallon, Nev.	0.92	0.89	1.06	1.07	0.88	0.88	0.99
Yuma, Ariz.	0.87	0.82	0.92	0.86	0.83	0.81	0.93
Mean	0.86	0.99	0.92	0.86	0.93	0.92	0.84
Probable error	±0.019	±0.025	±0.023	±0.028	±0.024	±0.019	±0.026

for the temperature and sunshine. Sunshine records were not available at all the evaporation stations, and the ratios given were obtained from Weather Bureau records for 30 stations in the region in which the evaporation tanks were located.

It will appear from the ratios given in Table IV, that the evaporation during 1912 was abnormally low. The evaporation during April was 14 per cent below normal. However, the average number of hours of sunshine during April was also 7 per cent

below normal, which would account at least in part for the diminished evaporation. May was normal, both with respect to evaporation and hours of sunshine. The evaporation for the first half of June, during which the eruption of Mt. Katmai occurred, was 8 per cent below normal; the second half of June was 14 per cent below normal; July, 6 per cent below; August, 8 per cent below; and September, 15 per cent below. The number of hours of sunshine was also somewhat below normal during this period. The Weather Bureau sunshine records are obtained with the Marvin sunshine recorder, which is essentially a differential thermometer in vacuo, one bulb being blackened. When the rate, at which solar radiation is received, is sufficient to develop a certain difference in the temperature of the bulbs, the sun is recorded as shining. It is evident that any reduction in the intensity of the solar radiation in midsummer (due to dust in the atmosphere or other

TABLE IV

RATIO OF THE EVAPORATION, SUNSHINE, AND TEMPERATURE IN 1912 TO THE CORRESPONDING NORMALS

	APRIL	MAY	JUNE 1–15	JUNE 16–30	JULY	AUGUST	SEPTEMBER
Evaporation..	0.87	0.99	0.92	0.86	0.94	0.92	0.85
Temperature.	1.00	1.03	0.95	0.96	0.97	0.98	0.88
Sunshine.....	0.93	1.01	1.01		0.93	0.97	0.92

causes) would enter into the records from this instrument as a reduction in the number of hours of sunshine. The observed reduction in sunshine (Table IV) following the eruption may therefore be attributed, in part at least, to a reduction in the intensity of the solar radiation transmitted by the upper atmosphere, rather than to an actual increase in cloudiness. There is obviously no way of separating these two factors from a consideration of the sunshine records alone.

It thus appears that the average evaporation as measured at 15 stations was below normal during the four months following the eruption of Mt. Katmai, the average reduction in evaporation being about 10 per cent. This is somewhat less than the observed reduction in the intensity of solar radiation as reported

by Abbot and Fowle and by Kimball, if we assume that for small changes in radiation, the evaporation is directly proportional to the radiation received. In this connection, it should be recalled that the pyrheliometer measurements deal only with the direct rays of the sun. Since the scattered radiation would be proportionately somewhat increased by the dust, the actual reduction in radiant energy during 1912 was probably not quite so great as indicated by the solar measurements. This would tend to bring the results more nearly in accord with the evaporation measurements.

In addition to measurements of the energy of the direct solar beam, Abbot and Fowle[4] have also measured the total sky radiation and the absorbed radiation. In former years, the sum of the three parts of the solar radiation has found to fall below the value of the solar constant by not more than 0.05 calorie. Their measurements in 1912, however, show an outstanding difference of about 0.28 calorie, which they attribute to the greater diffuse reflection of the atmosphere resulting from the haziness. This amounts to a reduction in the intensity of the solar radiation at the earth's surface of about 10 per cent, a value which is in good agreement with the observed diminution in evaporation. The reduction in the mean evaporation at the 15 observing stations following the haze of 1912 thus appears to afford an approximate measure of the reduction in the intensity of the solar radiation at the earth's surface.

RADIOTELEGRAPHY.—*A crystal contact disturbance preventer for radiotelegraphic receiving.* L. W. AUSTIN, U. S. Naval Radiotelegraphic Laboratory.

In 1908 I published the results of a study of the rectifying action of certain contacts, silicon-steel, carbon-steel, and tellurium-aluminum. Soon after this it occurred to me that the property of rapid change of resistance with impressed voltage shown by these contacts might be made use of in shunting to earth loud interfering signals and atmospheric disturbances, so trouble-

[4] loc. cit., p. 13.

some in radiotelegraphic receiving, and in the spring of 1909 very encouraging results were obtained from a tellurium-aluminum contact placed around the primary of the receiving transformer.

It was found however, that in actual service, while occasionally remarkable results were obtained in cutting out disturbances, the tellurium-aluminum contact was too unstable to be depended upon. Silicon in contact with metals was found to be less sensitive than the tellurium contact and also too unstable for practical use. Iron pyrites, zinkite, galena, and many other crystals have been tried at various times and unsuccessful experiments were also made with the Lodge-Muirhead mercury

TABLE I

DISTURBANCE PREVENTER	
IN	OUT
Deflection	Deflection
mm.	mm.
0.5	0.5
1.5	1.5
3.5	4.5
7.0	22.0
15.0	130.0
21.0	240.0
40.0	off scale
2.5	2.5

coherer, several other types of coherers, with vacuum valves and the electrolytic detector. It has recently been found that silicon in contact with certain crystals, especially with metallic arsenic, of which the dark colored impure variety is the best, forms a practical device for leading strong disturbances to earth without interfering with the reception of the regular signals.

Table I shows the detector galvanometer deflections with the disturbance preventing circuit in and out, the antenna being excited by a tuned buzzer circuit with different degrees of closeness of coupling.

Table II shows the relation between tuned buzzer circuit signals and natural atmospherics, the maximum throw of the

galvanometer during a period of 10 seconds being taken as the atmospheric reading.

The disturbance preventer is more effective in the case of strong interfering signals than against atmospheric disturbances, as it is quite possible to read signals of twenty times audibility thru disturbing signals of many hundred times audibility on the same wave length. The best results are obtained with loose coupling and with a considerable amount of inductance in the antenna, with a series condenser if necessary, and the disturbance preventer contact shunted across only that part of the inductance which acts as the primary of the receiving transformer.

TABLE II

DISTURBANCE PREVENTER			
IN		OUT	
Deflection		Deflection	
mm.		mm.	
Signal	*Atm.*	*Signal Approx.*	*Atm.*
10	7	12	51
"	7	"	80
"	6	"	75
"	8	"	62
"	6	"	68

An increase of the effect may be obtained by throwing the circuit out of tune to the loud signals by placing disturbance preventers across the capacity or across other portions of the inductance, and also in the secondary circuit. But in general, except under extraordinary circumstances, these introduce complications in handling which are out of proportion to their benefit.

Fairly good results have been obtained also with a contact of carborundum with other crystals. These combinations however, while more stable under extremely powerful disturbances, in general do not fall low enough in resistance to give as satisfactory results as the silicon-arsenic. I wish to express my indebtedness to my assistant, Chief Electrician Mineratti in the latter portions of this work.

GEOPHYSICS. *Data on the intrusion temperature of the palisade diabase.* R. B. SOSMAN and H. E. MERWIN, Geophysical Laboratory.

In his report on the petrography of the Newark igneous rocks of New Jersey,[1] Prof. J. Volney Lewis has described an interesting type of inclusion which occurs frequently in the Palisade diabase. Slabs of the underlying Newark shale and arkose sandstone have been "floated" up into the igneous rock until they stand at various angles between horizontal and vertical. In connection with an investigation on the specific volumes of rocks at high temperatures it became of interest to compare the specific volumes of the included and including rocks in this type of inclusion. Professor Lewis very kindly supplied us with specimens for the purpose, and our indebtedness to him both for material and for published descriptions is here acknowledged.

The specimens first obtained were from the quarry of the Fairview Stone Crushing Company, at the north end of the diabase hill between Fairview and Granton, New Jersey. This mass is an offshoot of the great Palisade sill which outcrops along the west bank of the Hudson River and extends southwest thru New Jersey. It lies only 800 feet west of the western border of the main sill, and is not over 200 feet vertically above the upper surface of this sill.[2]

In 1907 there was visible in the quarry mentioned "an arkosic sandstone slab about 10 feet thick at one end and tapering to about 5 feet at the other and over 100 feet long, lying at an angle of about 10 degrees with the horizon. This inclusion is within 10 feet of the bottom of the diabase sheet, which here rests on thinly laminated black and gray shales." We are informed by Professor Lewis that since that time quarrying operations have followed this slab back until it joined the underlying strata, thus establishing its connection with the floor of the intrusive mass. It was, therefore, not possible to obtain specimens of the actual inclusion, but specimens of the underlying arkosic sand-

[1] Geol. Surv. New Jersey, Ann. Rep., 1907, pp. 97-167. See, in particular, pls. 27 and 28, and p. 135.

[2] J. V. Lewis, Geol. Surv. New Jersey, Ann. Rep., 1906, p. 122; H. B. Kuemmel, ibid., 1897, p. 73.

stone and shale, apparently continuous with the floated slab, were obtained.

A preliminary experiment, made by heating specimens of the diabase and the arkose side by side in a platinum crucible, showed that at a temperature where the diabase would flow readily, the sedimentary rock was also partly fused, altho in the original inclusion there was no indication of fusion. The authors therefore undertook, as a side issue to the main question of the volume relations, a brief study of the relative fusing temperatures of the rocks in question. The results, while necessarily incomplete because of the complexity of the rocks and the unknown factors involved, show that the temperature at which the diabase was intruded must have been considerably lower than the temperature necessary to liquefy this diabase in the laboratory. This fact has long been suspected, altho there has been hitherto very little quantitative evidence bearing on the question.[3]

The diabase. There is no published analysis of the rock from this particular locality, but the rock is very similar to the "basaltic diabase" in the near-by railroad tunnels thru the Palisade sill, and to that of Rocky Hill.[4] Mr. Hostetter's determinations on our specimen gave 0.6 per cent water at 105°, 8.74 per cent FeO, and 1.51 per cent Fe_2O_3. The character of the rock would be approximately represented by the following weight percentage composition: SiO_2 51, Al_2O_3 13, CaO 10.5, MgO 7.5, FeO 8.5, Fe_2O_3 1.5, alkalies 3.5, TiO_2 1., water and miscellaneous 1.5. Its density at 20° was 2.97.

The rock is fine grained, and consists of a dense holocrystalline mass of feldspar and augite, with phenocrysts of pyroxene and of plagioclase feldspar. Minor minerals are biotite, magnetite, and occasional olivine.

Fusion of the diabase. The tests were made by placing small fragments of the rock, wrapped in platinum foil, in an electrically heated furnace held at a constant known temperature, measured by a thermoelement and potentiometer. After exposure to this

[3] See F. E. Wright, Intrusive Rocks of Mt. Bohemia, Geol. Surv. Michigan, Ann. Rep., 1908, p. 391.

[4] Geol. Surv. New Jersey, Ann. Rep., 1907, p. 121, analysis 4, 5, and 12; and pl. 16. Description, pp. 126-128.

temperature for a measured time, the rock was quenched by fusing off its supporting wire and dropping it out of the furnace into a basin of mercury. Microscopic examination then showed what changes had taken place at the high temperature. A fresh fragment was of course used for each test.

The lowest temperature at which tests were made was 751°. After the diabase had been held at this temperature for fifteen minutes, and then quenched in mercury, the phenocrysts of feldspar and pyroxene showed no change whatever; in the augitic groundmass a red brown mineral had formed, having an index of refraction of 1.74 and resembling certain basaltic hornblendes high in ferric iron.

There were no indications of fusion at 751°, nor at 850°, 953°, 1035°, 1052°, and 1101°. Fragments of the rock were held fifteen minutes at the first four of these temperatures, and seventy-five minutes at the last two. All gave practically the same result as the quenching at 751°, except that the red brown mineral decreased in amount with rising temperature. A dusty yellow-brown material which could not be identified, appeared in small amount at 1101°.

After seventy-five minutes at 1150° the phenocrysts were still unchanged, but the clear red-brown hornblende (?) had disappeared. A dusty yellow-brown substance, too dark for the determination of its optical properties, appeared to coat other minerals in films, and showed a few bubbles in places. Its occurrence suggested strongly the beginning of fusion of the lowest melting portion of the rock. Fifteen minutes at 1175° gave a little dark glass which could be positively identified, so that we may take 1150° as the approximate beginning of the temperature-interval of fusion. Feldspar and pyroxene phenocrysts remained unchanged at 1175°.

Fifteen minutes at 1200° produced considerable brownish bubbly glass of refractive index 1.60–1.61, and fused nearly all the pyroxene phenocrysts. Seventy-five minutes at the same temperature practically removed the pyroxene and gave a more homogeneous glass, none having refractive index above 1.60. The feldspar phenocrysts, except around their borders, remained unchanged.

The fragments of rock had an external appearance of incipient fusion.

Seventy-five minutes at 1225° caused the fragment to flow. About a third of the feldspar remained; the remainder was glass, containing dark brown octahedral and cubic grains which formed out of the glass. These grains had the high refraction of spinel. Heatings of fifteen and sixty minutes at 1250° fused or fluxed still more of the feldspar but did not remove it entirely. Fifteen minutes at 1302° left only traces of feldspar, and produced a clear glass, of refractive index equal to and slightly less than 1.60.

With its present composition, therefore, and under atmospheric pressure the diabase can not flow at a temperature below 1150° (at which temperature the lowest melting portion probably fuses), and does not flow appreciably below 1225°. It is completely liquid at about 1300°.

The inclusions. These consist both of feldspathic sandstone and shale. "The thinner portions of the sandstone inclusions are very hard and compact, and look in all respects like fine-grained, light colored granite. . . . From this facies every gradation is found to apparently normal feldspathic sandstone (arkose) in the thicker portions, showing little sign of alteration."

Fusion of included arkose. We obtained from Professor Lewis a specimen of arkose which had been entirely surrounded by coarse grained diabase under conditions where it must have taken up the temperature of the molten rock, and so situated that it could not have been traversed by mineralizing solutions after the solidification of the rock. This specimen was from the Palisade sill, in the Pennsylvania Railroad cut east of Marion station, Jersey City, where "thin sheets of arkosic sandstone, perhaps originally continuous, lie in an irregular undulating position in the diabase."[5] This inclusion varies in thickness from 4 inches to 3 feet (10–90 cm.). The fragments examined were not over 2 cm. from the diabase.

The metamorphosed arkose consists chiefly of quartz and orthoclase. New growth of orthoclase is visible around some of the original grains. It is all somewhat dusty, probably from subsequent alteration, altho biotite and hornblende, also present,

[5] J. V. Lewis, loc. cit., 1907, p. 135, (4), and pl. 28.

are very fresh. The latter minerals and magnetite appear to have originated chiefly from chloritized biotite originally present in the arkose, altho the surrounding magma may have contributed to their growth. One of the specimens showed, in a small cavity, well terminated crystals of quartz, orthoclase, and hornblende, apparently outgrowths of these minerals in the arkose. Calcite and datolite, which are found in some parts of the underlying arkose, are not found in this inclusion.

The characteristics just mentioned show that this rock could never have been fused. The retention of original cross-bedding in another specimen[6] is certain proof that the arkose could not have flowed.

Heated for thirty minutes at 1023°, this arkose showed no trace of glass. The biotite and hornblende were destroyed, feldspars more clouded, magnetite and quartz unchanged. After seventy-five minutes at 1150° the rock was more than half fused to a bubbly glass of refractive index 1.490 to 1.502. The feldspars were all fused, and only quartz and magnetite remained. Such a rock containing unaltered feldspar might fuse at a somewhat different temperature, but inasmuch as the feldspar was altered in part before the intrusion of the diabase the temperatures here observed are applicable.

Fusion of underlying arkose and shale. As mentioned above, we also obtained thru Professor Lewis specimens of the underlying arkose and shale at Granton, and it was upon these that the preliminary fusion tests were made. It was only after several measurements had been made on both rocks that datolite (which does not occur uniformly, and is sometimes entirely absent) was found in the arkose. Its presence renders the tests on these rocks inconclusive, but the results are included as a matter of record.

Our specimen of the underlying arkose at Granton consisted of about two-thirds alkali feldspars and nearly one-third quartz, with some augite, the latter being in crystals partly inclosing feldspar and quartz, as tho derived from constituents of the near-by diabase and from chloritized biotite present in the arkose before the intrusion. The feldspars had clear borders which had evi-

[6] Loc. cit., 1907, p. 135, (3).

dently grown upon the original feldspar grains, partly filling the pores of the rock with fresh feldspar. Calcite and datolite also occurred as pore-filling minerals.

Heated for fifteen minutes at 950°, the arkose showed no external change. A small amount of glass was found, formed by the fusion of datolite. The quartz appeared unchanged. After fifteen minutes at 1150°, glass was again present, resulting as before from fusion of datolite. Seventy-five minutes at the same temperature produced 10 to 15 per cent of glass of index 1.50–1.52. The orthoclase had begun to fuse around the edges of crystals and around the inclusions contained in the crystals.

Our specimen of the underlying shale was a very fine grained rock of density 2.59, banded with white and blue-black streaks, and having coarser lenses containing garnet. In the white portion quartz was identified, and probably andalusite.

Heated for fifteen minutes at 950°, the finest grained parts of the rock showed no marked change and no glass could be found. Fifteen minutes at 1150° caused the fragment to flow, and seventy-five minutes at the same temperature converted over one-half of it into glass of refractive index 1.51 and less, with a few fragments of original quartz remaining. But the extremely fine grain of the rock rendered it unsatisfactory for these experiments.

Both the shale and the arkose just described contained minerals of secondary origin resulting from the intrusion. Some of these probably formed during the period of cooling; therefore effects produced by heating these rocks might be quite different from those which might have been caused at the same temperature in the original rock.

Conclusion. The foregoing facts may be summarized in the following statements: (1) The "basaltic" facies of the Palisade diabase begins to fuse at about 1150°, and enough of it is fused at 1225° to permit the rock to flow; (2) The arkose now found in the diabase in the form of inclusions is more than half fused at 1150°, but shows no fusion at 1025°. (3) These inclusions as actually found show no indication of fusion or flow.

As indicated by their present properties under atmospheric pressure, there is therefore a gap of at least 100°, and probably more, between the maximum temperature to which the arkose inclusions

could have been subjected, and the minimum temperature at which the diabase could have flowed. At the time of intrusion, therefore, either the fusion temperature of the arkose minerals was greatly raised by the conditions then existing, or the fusion temperature of the diabase was lowered, or both causes acted together.

From experiments not yet published, we know that there is a considerable net volume increase accompanying the fusion of the diabase; its mean temperature of fusion would therefore probably be *raised* by increased pressure. About the volume change of the arkose minerals we know nothing; but from geological evidence the depth of overlying rock was probably not great, in comparison with the depths and pressures necessary to produce large changes in their fusion temperatures.

The most likely agent that suggests itself to bridge the gap between the laboratory fusion temperature of the arkose and that of the diabase is the water which the evidence of the surrounding rocks shows to have been present in the magma. Its effect in lowering the fusion temperatures of silicates is quantitatively unknown, but qualitatively we know it may be very large. Other factors of perhaps less importance are the boric acid now found in the datolite of surrounding rocks, and the carbon dioxide and fluorine which may have been present.

The foregoing investigation may serve to emphasize a point which is all too frequently overlooked in current speculation on the fusion of rocks on the basis of the laboratory data now available. The conditions of fusion, differentiation, intrusion, and crystallization may have been modified, not slightly but profoundly, by volatile components of which only occasional traces are retained in the rock as we find it at the surface of the earth. To draw final conclusions, then, on the basis of any property possessed by a particular rock type or even by a particular specimen may lead us widely astray. This is not to say that the problems involving the effect of volatile components can not be solved, for experimental methods have been and are being worked out to handle them; but until we know in what directions and to what extent these volatile ingredients have modified the conditions of rock formation, extended generalisation is hazardous and of doubtful utility.

PHYSICS.—*An electrical goniometer furnace for the measurement of crystal angles and of refractive indices at high temperatures.* FRED. EUGENE WRIGHT. Geophysical Laboratory.

The measurement of the change in the optical properties and in the interfacial angles of crystals with change in temperature has long interested mineralogists, and many attempts have been

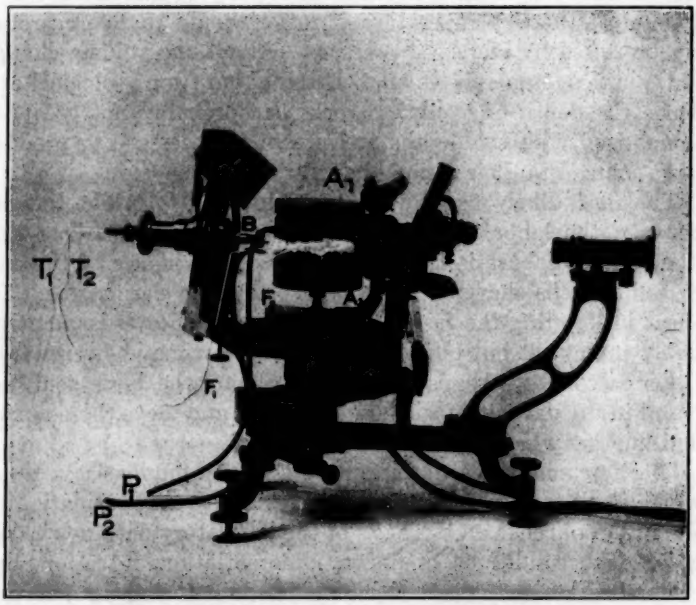

Fig. 1. Photograph of Goldschmidt's two circled goniometer with thermoelectric furnace attachment mounted in position ready for measurements. A_1, A_2, upper and lower water jackets; P_1, P_2, rubber tubing for circulation of water thru A_1, A_2; F_1, F_2, platinum wires, 0.4 mm. in diameter, of heating spirals in furnace; B, crystal holder extending into center of furnace; T_1, T_2, thermoelement wires.

made, since the pioneer work of Schrauf and Mallard, to devise satisfactory methods for the purpose. The introduction of electrical methods and appliances has greatly simplified the problem and recently F. Rinne[1] has successfully adapted an electric re-

[1] Neues Jahrb. Min. Geol. u. Pal., 1910, II, 139.

sistance furnace to the measurement of the refractive indices of prisms at temperatures up to 750°C. In the different heating devices, however, which have heretofore been employed, insufficient attention has been given to the furnace design with reference especially to the heat distribution and to accuracy of the temperature measurements, with the result that the data obtained are encumbered with unnecessarily large prob-

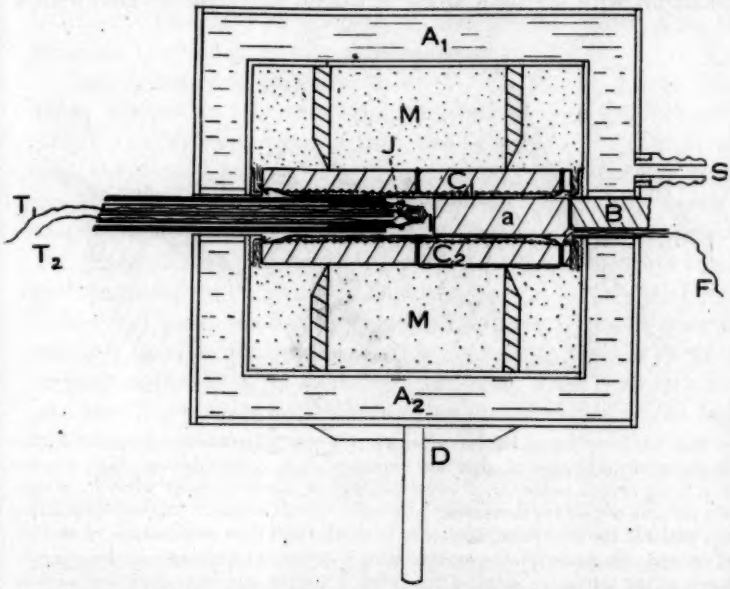

Fig. 2. Vertical section thru furnace and water jacket; A_1, A_2, water jackets; S, intake for circulating water; F, platinum furnace wires; C_1, C, alundum cake on inner faces of which platinum wire spiral is wound; a, alundum segment; B, asbestos ring; J, bare thermal junction; I, crystal; M, magnesium powder; D, supporting bar of furnace; T_1, T_2, thermoelement wires.

able errors. In the present furnace, the effort has been made to meet these objections and to produce an instrument of fair precision which may serve not only for the measurement of the interfacial angles of a crystal, but also for the direct measurement of its refractive indices at any temperature up to 1150°C., at

which temperature the light of the furnace becomes relatively intense and the measurements are correspondingly less satisfactory.

The furnace fits as an attachment on the Goldschmidt two-circled goniometer (fig. 1, *A*). It consists of two flat disks of alundum (7 cm. in diameter and 5 mm. thick) on one side of which a spiral of 1.75 mm. pitch is stamped;[2] into its grooves platinum wire 0.4 mm. thick is wound and then covered with a

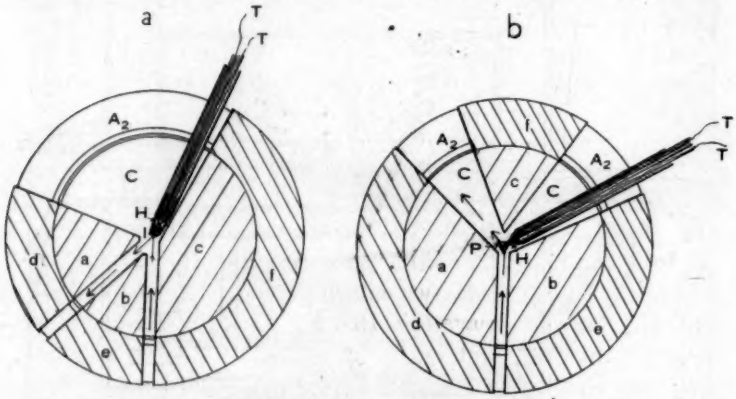

Fig. 3. Top view of furnace after water jacket A_1 has been removed. Figure 3a shows arrangement of alundum segments, *a*, *b*, *c*, of asbestos ring segments *d*, *e*, *f*, of crystal holder *H*, of crystal *I*, and of thermoelement wires *T*, in case the furnace is used for measuring interfacial crystal angles. The arrows indicate the paths of the rays from collimator to crystal and then to telescope of the goniometer. In figure 3b, the arrangement is sketched for the case of the measurement of the refractive index of the prism P by the minimum deviation method. The letters have the same significance as in figure 3*a*.

thin layer of alundum cement and baked at 1200° to 1300°C. These disks are backed by magnesia powder and mounted in hollow cylindrical water jackets (fig. 2) Their edges are shielded from direct contact with the water jackets by asbestos wool packing. The details of construction are evident from figures 1 and 2. Segments of alundum 10 mm. thick and of the shapes indicated in figure 3, *a*, *b*, *c*, are placed in position on top of furnace

[2] Made on special order by the Norton Company of Worcester, Mass.

cake C_2, and serve to support the upper furnace part A_1, (figs. 1 and 2). Outside of these segments asbestos ring segments are fitted as indicated in figure 3, *d*, *e*, *f*. Since alundum is a good conductor of heat the alundum segments tend effectively to render the heat distribution uniform at the center of the furnace while the outside asbestos rings are poor conductors and tend to confine the heat properly. In figure 1 asbestos wool has been used in addition to the asbestos rings as an extra precaution. The furnace opening at the crystal holder B is also shielded to some extent by asbestos wool.

Heat is supplied thru the wires, F_1, F_2 (fig. 1), 4.5 to 5 amperes current at 110 volts being required to heat the furnace to 1150°. Cold water passing thru the tubes, P_1, P_2, (fig. 1) and and the water jackets, A_1, A_2, completely protects the goniometer parts from the heat. Temperatures are read by means of the thermoelement (T_1, T_2, fig. 1) either on a millivoltmeter of the Siemens and Halske type or on one of the potentiometer-galvanometer systems of this laboratory.

In order to adapt the two circled goniometer to such measurements a special carriage (fig. 1,*B*) was made to replace the usual crystal centering and adjusting carriage. This part is hollow and into it a porcelain tube is inserted on the end of which small platinum jaws are fitted, similar to those used in the thermal microscope recently described.[3] In these jaws the crystal is mounted and adjusted before the furnace parts are set in position. Thru the carriage B and the porcelain tube holder the thermoelement wires (0.2 mm. in diameter and enclosed in fine porcelain tubes) pass and are so adjusted that the bare thermal junction of the thermoelement is in direct contact with the crystal.

After the crystal has been adjusted and centered approximately in the platinum jaws, the furnace part A_2 is raised to about the position indicated in figure 2. The alundum and asbestos ring segments are then put into position and the upper furnace A_1 placed on them. After the proper electric and water

[3] This Journal, **3**: 232–236. 1913.

jacket connections have been made, the furnace can be carried to any temperature up to 1150° and the crystal angles or the refractive indices of a prism measured by the ordinary room temperature methods which are in general use. As the crystal is enclosed in the furnace a dark room is not necessary for the measurements.

As noted above the adjustment of the crystal or prism is done practically by hand both by moving and tilting the crystal slightly and by bending the platinum jaws as a whole. In the present apparatus this procedure is often tedious and it is planned to modify the present adjustment device so as to facilitate this part of the procedure. For crystal angle measurements this adjustment is unnecessary because the theodolite principle is there used and any direction in the crystal may serve as a pole, the proper reduction of the observed position angles being made later by routine calculation. The arrangement of the alundum segments in the furnace for the measurement of crystal angles is indicated in figure 3a, while that for measuring the refractive indices of properly oriented crystal prisms by the minimum deviation method is shown in figure 3b. The methods of measurement followed are the standard room temperature methods and need not be described here.

It may be of interest to note that recent preliminary measurements in the goniometer furnace on a cleavage rhomb of calcite indicate that the cleavage angle of calcite at 600°C is 75°52′, while at room temprature (30°) it is 74°55′, a change in the cleavage angle of nearly one degree during a temperature rise of about 600°. At 700° the calcite crystal faces lose their lustre and become white (formation of CaO) and are valueless for goniometric work. The above change in cleavage angle indictes an average increase of 1 minute in angle for every 10° temperature rise. It would seem, therefore, that the practice of expressing crystal angles to seconds of arc without giving the temperature at the time of measurement can serve little purpose and is in fact illusory as regards the actual accuracy implied.

An extended series of measurements of the change of the optical properties and crystallographic angles of the rock making

minerals with temperature rise has been commenced at the Geophysical Laboratory—the birefringence, extinction angles, and optic axial angles being measured on the new thermal microscope while the refractive indices and crystal angles are measured on the thermoelectric goniometer furnace. In each case only minerals of definitely known composition are to be taken and the temperatures of melting and of inversion controlled by the heating and quenching methods now in use in this laboratory. Accurately oriented crystal sections are to be ground on a new crystal grinding goniometer which is now practically finished in the workshop of the laboratory. With this instrument, in which the device for autocollimation described recently in this Journal[4] has been adopted, it will be possible to orient and to grind crystal plates with reference either to their crystallographical directions or to their optical directions.

So far as can be judged from preliminary measurements, the results obtained with the electrical goniometer furnace on favorable material, are accurate to about 5° in temperature, about 1′ in crystal angle readings and 1 or 2 in the fourth decimal place in refractive index measurements.

The three instruments—new thermal microscope, goniometer furnace attachment, and crystal grinding goniometer,—render possible the quantitative study of crystallography and of mineral optics at high temperatures. Such study should add materially to an understanding of the crystallographic forces and of their relation to other physical forces, such as internal friction and surface tension.

[4] This Journal, **3**: 235. 1913.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this journal and abstracts of official publications should be transmitted thru the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

ASTRONOMY.—*Determination of time, longitude, latitude and azimuth.* WILLIAM BOWIE. Special Publication No. 14 of the U. S. Coast and Geodetic Survey, 1913.

This is the latest issue of a series of manuals prepared by the U. S. Coast and Geodetic Survey for the guidance of the astronomic observer in the field and the computer in the office, in carrying on the geodetic astronomy of the Survey in a systematic manner.

This publication necessarily contains much data that appeared in the fourth edition but there is also much new material, the principal items of which are: The determination of time and longitude, using the transit micrometer; a description of the transit micrometer; determination of time with the vertical circle for use in connection with azimuth observations; a description of the method of observing azimuth coincidently with horizontal directions in primary triangulation; an example of the determination of an azimuth in Alaska with a transit equipped with a transit micrometer; examples of the records and computations in the different classes of work, as actually made at present by the Survey; and statements of the field cost of the different classes of work.

W. BOWIE.

GEODESY.—*The California-Washington Arc of Primary Triangulation.* A. L. BALDWIN. Special Publication No. 13, U. S. Coast and Geodetic Survey, 1913.

In the spring of 1903 the U. S. Coast and Geodetic Survey began the reconnaissance for an arc of primary triangulation to extend from the primary triangulation in northern California to Puget Sound. The work of reconnaissance was not done continuously in any one season,

but was done a little at a time, in order to interfere as little as possible with the observations. The observing was completed in four summer seasons, beginning in June, 1903, and ending in July, 1906.

The length of the primary triangulation of this arc, along the axis of the scheme, is 577 miles (929 kilometers) and the length of the subsidiary schemes, secondary in character, is about 30 miles (48 kilometers). Fifty-seven stations constitute the main scheme. The mean latitude of the three old stations of the Thirty-ninth Parallel triangulation, from which the arc started, is 39° 05′, and the northernmost point lies in latitude 47° 23′. The triangulation follows closely the meridian of 122° 30′.

There were used to control the lengths in this triangulation the Yolo base in California, the Willamette base, near Eugene, Oregon, and the Tacoma base, near Tacoma, Washington. The Yolo base was measured in 1881 in connection with the transcontinental triangulation, while the other two bases were measured in 1906.

Each of the triangulation stations was well marked and hence is available for the surveyor and engineer. The publication contains descriptions of the location and marking of the stations, also the latitude and longitude of each point in the scheme and the azimuth of each line observed over for horizontal directions.

A series of sketches and an index enable one to find readily the data for any portion of the area covered by the triangulation. W. BOWIE.

GEOLOGY.—*The Onondaga fauna of the Allegheny region.* E. M. KINDLE. U. S. Geological Survey Bulletin 508. Pp. 144, with a map and sections.

The Onondaga limestone is represented from Hudson River to Lake Erie by a zone of frequently recurring outcrops across central New York State. Passing under Lake Erie, the fauna reappears in rocks of the same lithologic facies in northern and central Ohio, and reaches as far west as Louisville. The most westerly recorded appearance of the fauna is at the Bake Oven, in southwestern Illinois, so that it has an east-west extension of about 1000 miles. In sharp contrast with this considerable westerly extension of the Onondaga fauna beyond its type region in eastern New York is the comparatively insignificant southerly extension of the fauna and formation as it has been generally recognized. The formation barely crosses Delaware River, according to most of the papers dealing with the stratigraphy of the Devonian in the Allegheny region, which give it a north-south extension of scarcely 200 miles. This

insignificant southerly extension of a fauna which has been recognized as so persistent in a westerly direction seems more surprising when it is recalled that nearly all the other faunas characterizing the major divisions of the New York Devonian section have been traced southward from New York entirely across Pennsylvania into the Virginias. Thus, it is seen that the prevailing conception of the Onondaga fauna, which presumes its absence south of New York, gives to it an anomalous position as compared with the other important faunas of the Devonian section of New York. The evidence gathered during several seasons of field work in the Allegheny region indicates that this conception is not well founded, and that the southerly extension of the Onondaga fauna is quite comparable in distance with its westerly extension. The field studies have shown that the Onondaga fauna in the Allegheny region extends far south of the area in which nearly pure limestones were deposited during Onondaga time, into a region where shale-forming sediments partly or completely dominated those of calcareous type. This fauna has been found in nearly all the sections studied from New York to Tennessee.

The direct bearing of these new data on the paleography of Onondaga time is obvious. They indicate the extension of the eastern shore line of the Onondaga sea in a southwesterly direction from southeastern New York to the east of the Allegheny region instead of far to the west of it, as previously drawn in paleogeographic maps, across the States of Ohio, Indiana, and Kentucky. In the light of this new evidence it appears that the eastern shore line of the Onondaga sea trended southwestward across north-central New Jersey and southeastern Pennsylvania. It probably traversed the States of Maryland and Virginia near the present axis of the Blue Ridge. From southwestern Virginia this shore line appears to have trended westward not far from the Kentucky-Tennessee line as far as the valley of Tennessee River, where it resumed its southerly trend. E. M. K.

ENTOMOLOGY.—*Three interesting butterflies from eastern Massachusetts.* AUSTIN HOBART CLARK. Proceedings of the United States National Museum, **45**: 363–364; pls. 32.

Junonia cænia Hübner is recorded from Newtonville and from Coffin's Beach, near Annisquam; *Feniseca tarquinius* (Fabricius) is recorded from Newtonville; and a specimen of *Euphydryas phaëton* (Drury) from Newtonville representing the variety *superba* Streker is described and figured. A. H. C.

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